

# Summary of Field Quality Data in D4L103

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# Warm Measurements

- Warm measurements have been completed in all the nine D2 and the three D4 dipoles.
- Harmonics are measured with a 1 meter long mole at 10 axial locations in each aperture.
- Field angle is measured relative to gravity. Systematic error in calibration is removed by measuring field angles from both ends.
- Fiducials are surveyed on the test stand. The survey data are used to express field angles in the magnet frame.
- Integral transfer function is measured with a non-rotating, 10-meter long coil.
- All warm measurements are done before cold test.

# D4L103 Vs. Mean and Standard Deviation

## Integral Normal Harmonics (Warm) at 25 mm

	Left Aperture				Right Aperture			
	D2L/D4L Mean	D2L/D4L Std.Dev.	4103(L)	No. of Sigma	D2L/D4L Mean	D2L/D4L Std.Dev.	4103(R)	No. of Sigma
I.T.F. (T.m/kA)	5.9569	0.043%	5.9559	-0.4	5.9569	0.043%	5.9608	1.5
Quadrupole*	-5.34	0.61	-5.14	0.3	5.13	0.61	3.83	-2.1
Sextupole	-3.22	1.31	-4.35	-0.9	-3.22	1.31	-1.67	1.2
Octupole	0.10	0.16	-0.15	-1.6	0.10	0.16	0.19	0.6
Decapole	0.62	0.39	0.79	0.4	0.62	0.39	0.83	0.5
12-pole	-0.01	0.06	0.14	2.3	-0.01	0.06	0.05	0.9
14-pole	0.06	0.09	0.09	0.4	0.06	0.09	0.10	0.4
16-pole	0.00	0.02	0.01	0.3	0.00	0.02	0.04	1.7
18-pole	-0.14	0.03	-0.17	-1.0	-0.14	0.03	-0.10	1.2
20-pole	0.00	0.01	-0.01	-0.9	0.00	0.01	-0.03	-2.3
22-pole	-0.64	0.02	-0.65	-0.8	-0.64	0.02	-0.63	0.5
24-pole	0.00	0.01	0.00	0.0	0.00	0.01	0.00	0.3
26-pole	-0.26	0.01	-0.24	1.2	-0.26	0.01	-0.23	2.2

\* Mean values of the normal quadrupole term are treated as aperture dependent.

All other terms are considered aperture independent.

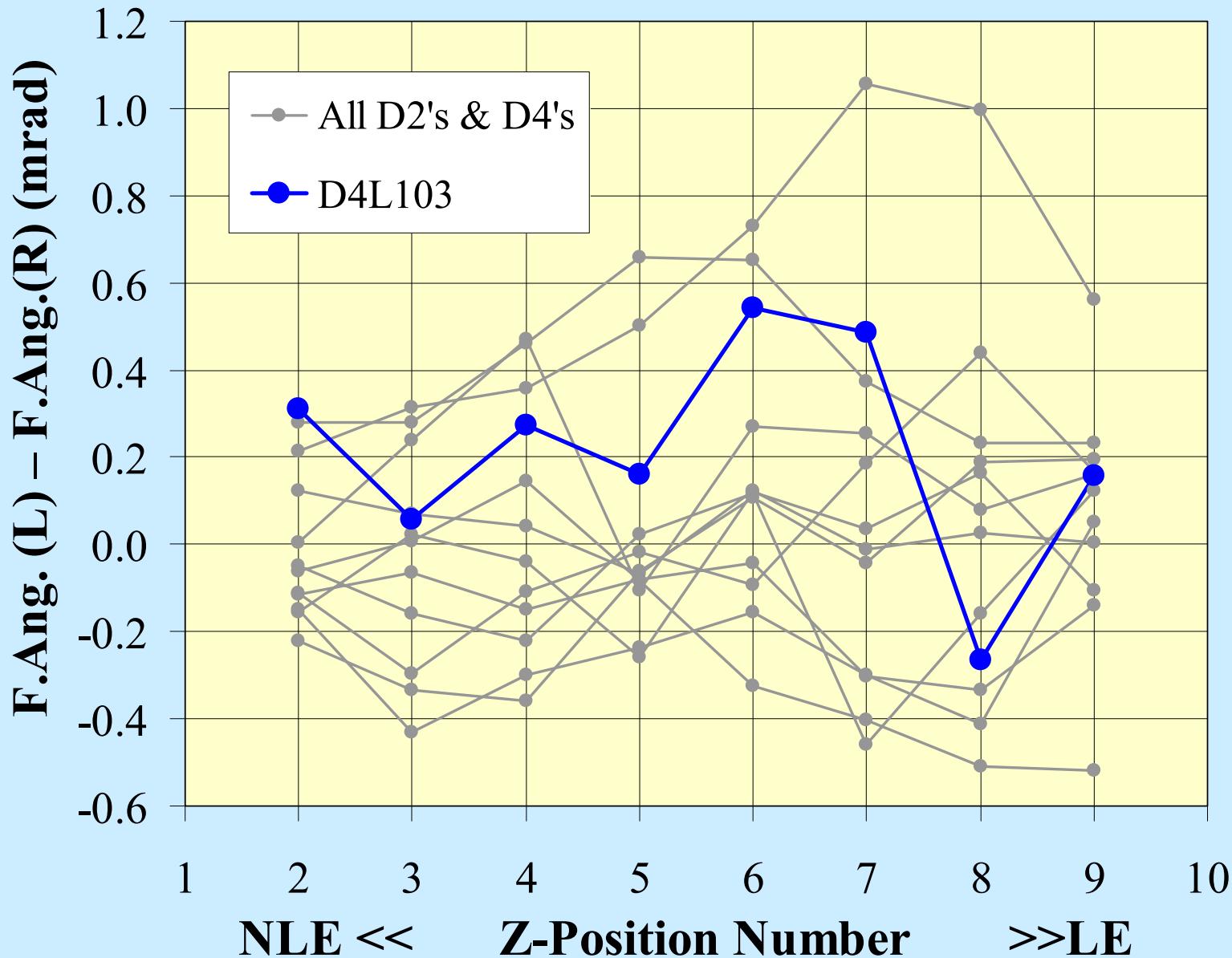
# D4L103 Vs. Mean and Standard Deviation

## Integral Skew Harmonics (Warm) at 25 mm

	D2L/D4L Mean	D2L/D4L Std.Dev.	4103(L)	No. of Sigma	4103(R)	No. of Sigma
Fld. Angle (mrad)	-0.36	0.20	<b>-0.22</b>	<b>0.7</b>	<b>-0.39</b>	<b>-0.2</b>
Quadrupole	0.05	1.90	<b>-1.27</b>	<b>-0.7</b>	<b>0.80</b>	<b>0.4</b>
Sextupole	-0.98	0.38	<b>-0.68</b>	<b>0.8</b>	<b>-0.56</b>	<b>1.1</b>
Octupole	0.16	0.61	<b>0.63</b>	<b>0.8</b>	<b>0.87</b>	<b>1.2</b>
Decapole	0.18	0.12	<b>0.28</b>	<b>0.8</b>	<b>0.39</b>	<b>1.8</b>
12-pole	0.03	0.17	<b>0.22</b>	<b>1.1</b>	<b>0.12</b>	<b>0.5</b>
14-pole	-0.09	0.03	<b>-0.18</b>	<b>-2.9</b>	<b>-0.05</b>	<b>1.2</b>
16-pole	0.01	0.04	<b>0.02</b>	<b>0.3</b>	<b>0.02</b>	<b>0.1</b>
18-pole	0.03	0.02	<b>0.01</b>	<b>-1.2</b>	<b>0.04</b>	<b>0.7</b>
20-pole	0.02	0.02	<b>0.00</b>	<b>-0.9</b>	<b>0.02</b>	<b>0.0</b>
22-pole	0.00	0.01	<b>-0.01</b>	<b>-0.8</b>	<b>0.00</b>	<b>0.0</b>
24-pole	0.01	0.01	<b>0.01</b>	<b>0.6</b>	<b>0.00</b>	<b>-0.9</b>
26-pole	0.00	0.01	<b>0.01</b>	<b>0.2</b>	<b>-0.04</b>	<b>-3.8</b>

Field angles are wrt reference frame defined by fiducials.

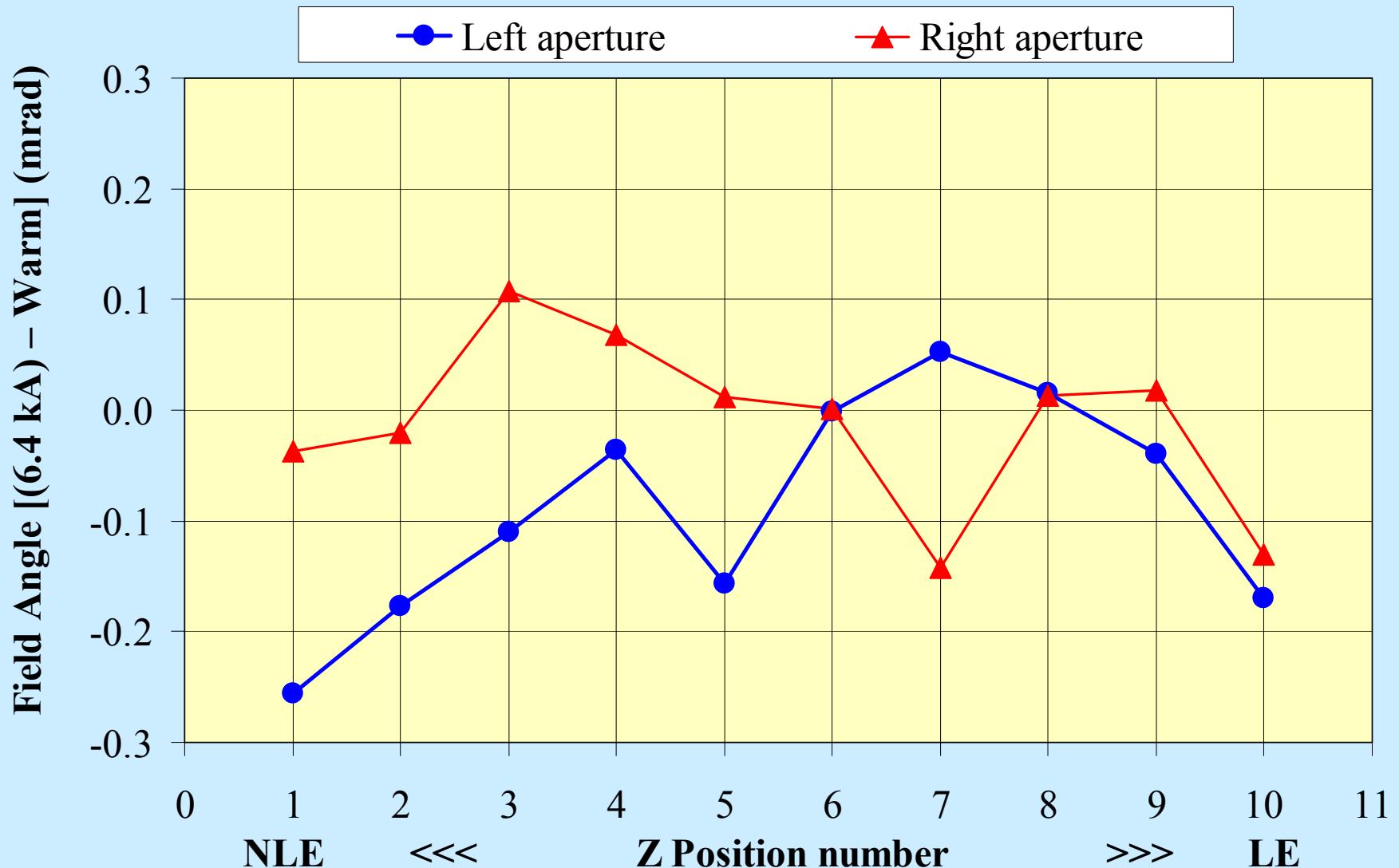
# Field Angle Alignment in D2/D4 Dipoles



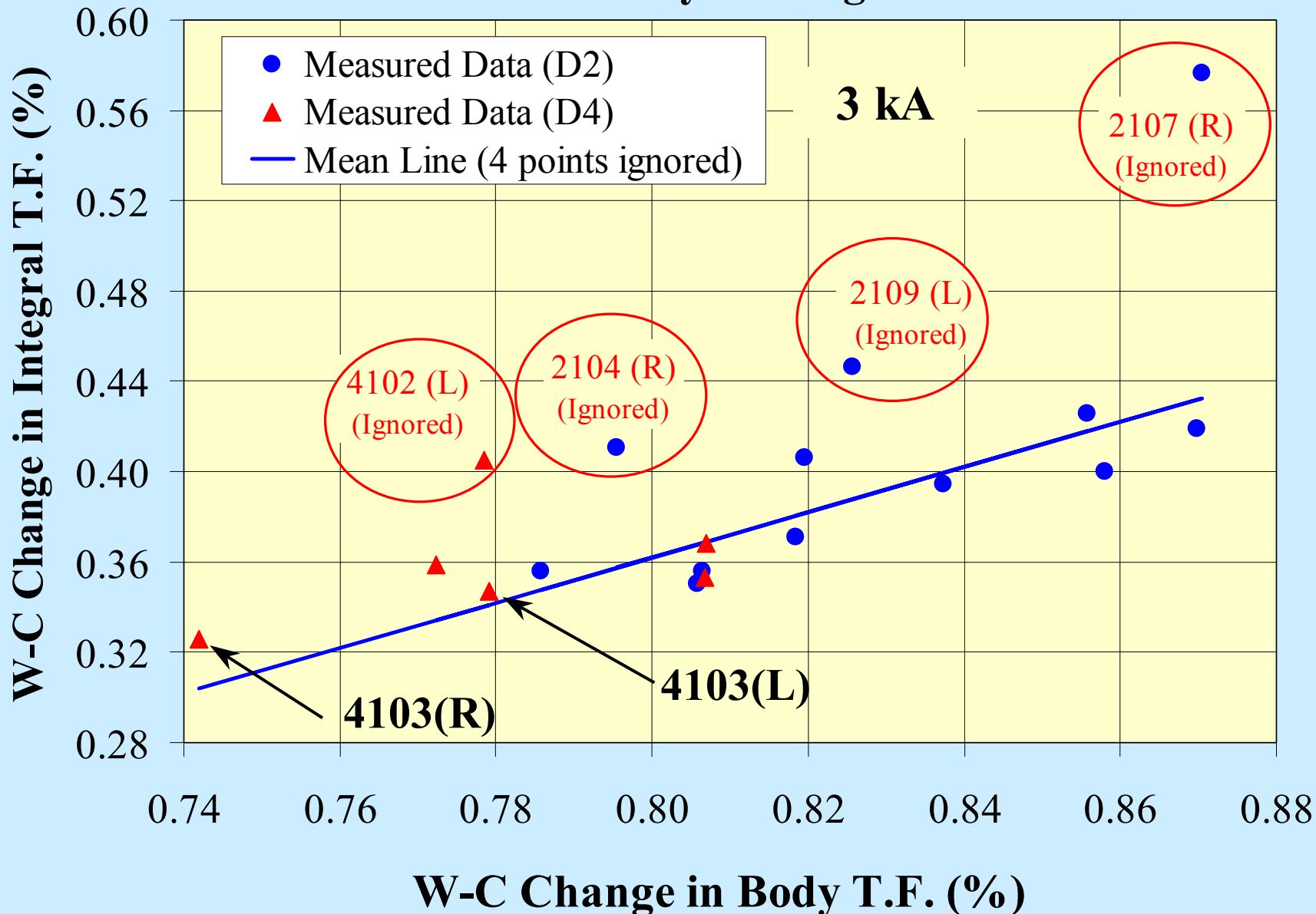
# Cold Measurements

- Only a minimal set of measurements was done in D4L103.
- Minimal set consists of a sparse excitation curve at each of the 10 axial positions, in each aperture.
- The 19 currents in the sparse loop cover 200A to 6400A, and are carefully chosen to catch all the “features” of a full excitation curve.
- The integral T.F. is obtained from Z-scan, and can have random errors of up to  $\sim 0.1\%$ .
- Down ramp measurements are done at only one position in each aperture.
- No dynamic measurements were made in D4L103.

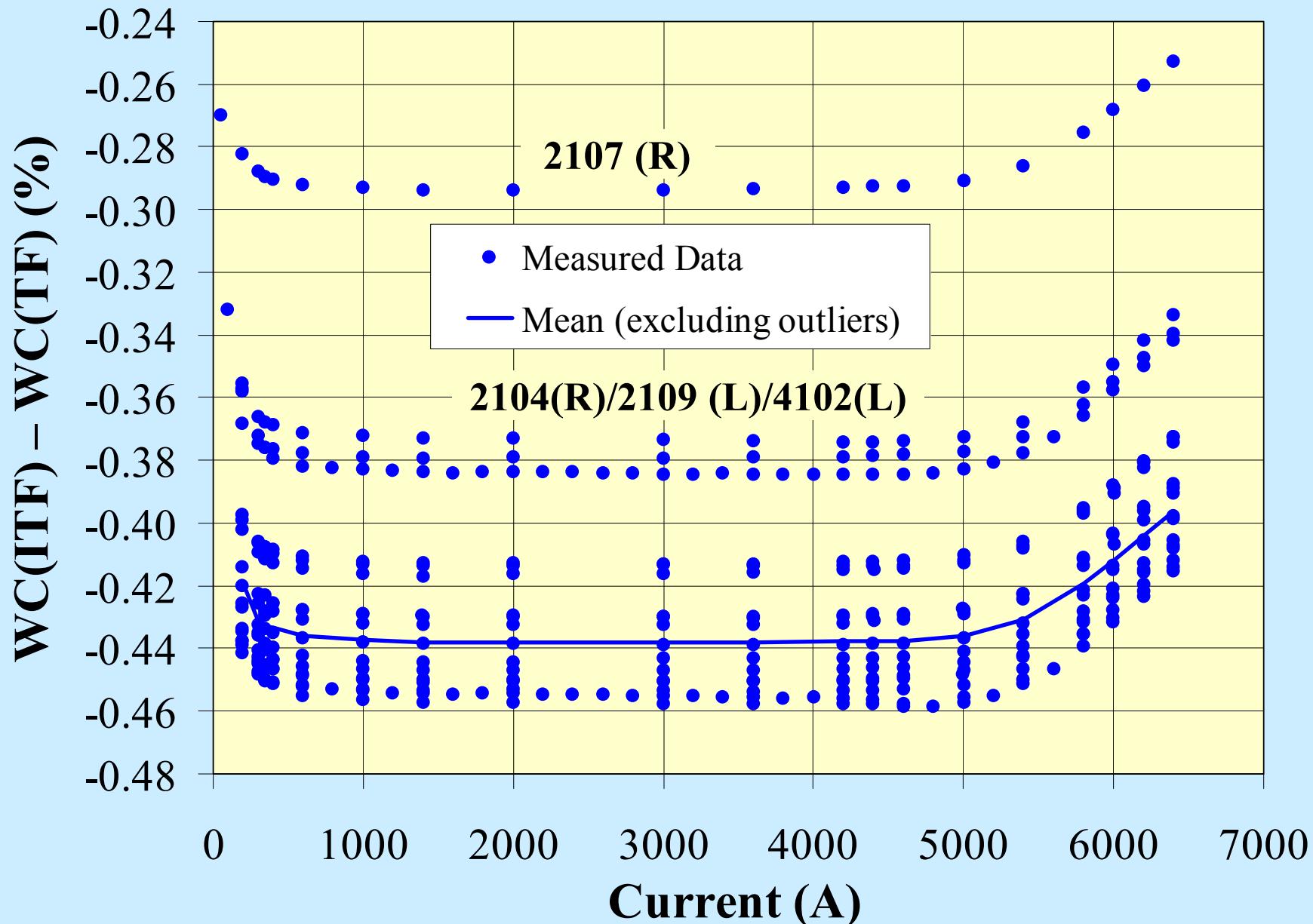
# Field Angle Changes on Cool Down in D4L103



# Correlation between Body & Integ. T.F. Warm-Cold



# Body TF and ITF W-C Offset differences as a function of Current



# Comparison of Field Quality in D4L103 with the Expected Ver 1.0 Tables

## Expected Ver 1.0 Table (25 mm)

Integral Harmonics at 315A (0.2 Tesla)

n	$\langle bn \rangle$	$\Delta (bn)$	$\sigma (bn)$	$\langle an \rangle$	$\Delta (an)$	$\sigma (an)$
2	0.08	0.77	0.28	-0.12	3.68	1.53
3	-9.92	5.52	1.95	-1.10	0.49	0.17
4	-0.05	0.20	0.08	0.13	1.15	0.42
5	0.64	0.83	0.40	0.18	0.16	0.06
6	-0.01	0.08	0.03	-0.03	0.54	0.15
7	-0.26	0.21	0.10	-0.09	0.07	0.02
8	-0.03	0.03	0.01	-0.01	0.15	0.05
9	0.14	0.13	0.04	0.02	0.03	0.01
10	0.03	0.05	0.02	0.02	0.05	0.02
11	-0.66	0.04	0.02	-0.01	0.02	0.01

## Measured Data in D4L103 & Ver 1.0 Comparison

Integral; 0.2 Tesla (interpolated) at 25 mm radius

n	$bn(L)$	$bn(R)$	$an(L)$	$an(R)$	$bn(L)$	$bn(R)$	$an(L)$	$an(R)$
2	4.92	-5.91	-1.07	0.70	??	??	OK	OK
3	-15.19	-13.32	-0.88	-0.71	OK	OK	OK	OK
4	0.20	-0.17	0.48	0.88	OK	OK	OK	OK
5	0.68	0.99	0.22	0.28	OK	OK	OK	OK
6	0.21	-0.03	0.24	0.04	??	OK	OK	OK
7	-0.26	-0.24	-0.27	-0.07	OK	OK	??	OK
8	-0.06	0.00	0.10	0.01	OK	OK	OK	OK
9	0.00	0.06	0.11	0.04	OK	OK	??	OK
10	0.00	-0.03	0.05	0.09	OK	OK	OK	OK
11	-0.79	-0.76	0.04	0.00	??	??	??	OK

Note: Large b2 at low fields was not foreseen in Ver 1.0 tables

## Expected Ver 1.0 Table (25 mm)

Integral Harmonics at 3.8 Tesla (6000 A)

n	$\langle bn \rangle$	$\Delta (bn)$	$\sigma (bn)$	$\langle an \rangle$	$\Delta (an)$	$\sigma (an)$
2	-0.07	0.79	0.28	0.53	3.71	1.51
3	1.99	3.57	1.70	-1.07	0.55	0.18
4	-0.21	0.21	0.08	0.05	1.08	0.41
5	0.04	0.80	0.39	0.19	0.17	0.06
6	-0.05	0.10	0.04	0.00	0.55	0.16
7	0.06	0.19	0.10	-0.10	0.06	0.02
8	-0.01	0.03	0.01	-0.01	0.15	0.05
9	0.00	0.12	0.04	0.01	0.03	0.01
10	0.03	0.05	0.02	0.03	0.04	0.02
11	-0.56	0.04	0.02	-0.01	0.01	0.01

## Measured Data in D4L103 & Ver 1.0 Comparison

Integral; 3.8 Tesla (6000 A) at 25 mm radius

n	$bn(L)$	$bn(R)$	$an(L)$	$an(R)$	$bn(L)$	$bn(R)$	$an(L)$	$an(R)$
2	-0.67	-0.14	-1.27	0.65	OK	OK	OK	OK
3	-2.34	0.33	-0.75	-0.61	OK	OK	OK	OK
4	0.14	-0.08	0.65	0.94	??	OK	OK	OK
5	0.20	0.35	0.25	0.33	OK	OK	OK	OK
6	0.20	-0.06	0.28	0.08	??	OK	OK	OK
7	0.22	0.21	-0.16	-0.06	OK	OK	OK	OK
8	0.01	-0.01	0.08	0.00	OK	OK	OK	OK
9	-0.17	-0.13	0.04	0.05	??	OK	OK	OK
10	0.03	-0.03	0.06	0.08	OK	OK	OK	OK
11	-0.63	-0.64	0.00	0.00	??	??	OK	OK

OK=Value between (mean- $\Delta-\sigma$ ) & (mean+ $\Delta+\sigma$ )

# Comparison of Field Quality in D4L103 with the Expected Ver 2.0 Tables

## Expected Ver 2.0 Table (at 25 mm radius)

Integral Harmonics at 315A (0.2 Tesla)

n	$\langle bn \rangle(L)$	$\langle bn \rangle(R)$	$\Delta(bn)$	$\sigma(bn)$	$\langle an \rangle$	$\Delta(an)$	$\sigma(an)$
2	4.08	-5.07	1.97	0.63	-0.03	5.99	1.56
3	-22.28	-22.28	1.87	1.50	-0.72	0.74	0.44
4	-0.08	-0.56	0.36	0.20	-0.84	0.65	0.41
5	1.17	1.17	1.20	0.85	0.21	0.25	0.18
6	0.04	-0.16	0.20	0.12	0.10	0.67	0.39
7	-0.40	-0.40	0.16	0.11	-0.13	0.08	0.05
8	-0.03	-0.03	0.04	0.03	-0.01	0.27	0.17
9	0.16	0.16	0.15	0.10	0.03	0.03	0.02
10	-0.03	-0.03	0.08	0.04	0.02	0.08	0.05
11	-0.77	-0.77	0.03	0.02	0.02	0.02	0.01

## Measured Data in D4L103

Integral; 0.2 Tesla (interpolated) at 25 mm radius

n	$bn(L)$	$bn(R)$	$an(L)$	$an(R)$
2	4.92	-5.91	-1.07	0.70
3	-15.19	-13.32	-0.88	-0.71
4	0.20	-0.17	0.48	0.88
5	0.68	0.99	0.22	0.28
6	0.21	-0.03	0.24	0.04
7	-0.26	-0.24	-0.27	-0.07
8	-0.06	0.00	0.10	0.01
9	0.00	0.06	0.11	0.04
10	0.00	-0.03	0.05	0.09
11	-0.79	-0.76	0.04	0.00

n	$bn(L)$	$bn(R)$	$an(L)$	$an(R)$
2	OK	OK	OK	OK
3	??	??	OK	OK
4	OK	OK	??	??
5	OK	OK	OK	OK
6	OK	OK	OK	OK
7	OK	OK	??	OK
8	OK	OK	OK	OK
9	OK	OK	??	OK
10	OK	OK	OK	OK
11	OK	OK	OK	OK

## Expected Ver 2.0 Table (at 25 mm radius)

Integral Harmonics at 3.8 Tesla (6000 A)

n	$\langle bn \rangle(L)$	$\langle bn \rangle(R)$	$\Delta(bn)$	$\sigma(bn)$	$\langle an \rangle$	$\Delta(an)$	$\sigma(an)$
2	-0.50	-0.77	1.02	0.32	-0.67	5.94	1.55
3	-4.17	-4.17	1.63	1.47	-0.84	0.69	0.43
4	-0.01	-0.63	0.29	0.18	-0.38	0.56	0.40
5	-0.13	-0.13	1.14	0.85	0.21	0.24	0.18
6	0.04	-0.17	0.05	0.03	-0.02	0.58	0.38
7	0.15	0.15	0.12	0.10	-0.11	0.06	0.05
8	0.00	-0.04	0.03	0.03	0.01	0.25	0.17
9	-0.09	-0.09	0.13	0.10	0.05	0.02	0.01
10	-0.01	-0.01	0.05	0.03	0.00	0.05	0.03
11	-0.62	-0.62	0.02	0.01	0.00	0.03	0.02

## Measured Data in D4L103

Integral; 3.8 Tesla (6000 A) at 25 mm radius

n	$bn(L)$	$bn(R)$	$an(L)$	$an(R)$
2	0.22	0.16	0.30	-2.00
3	-1.54	-0.94	-0.37	-0.45
4	0.42	-0.21	0.55	-0.44
5	0.21	0.46	0.34	0.32
6	0.09	-0.10	0.19	-0.11
7	0.21	0.26	-0.04	-0.06
8	0.02	-0.04	0.02	0.02
9	-0.18	-0.16	0.05	0.06
10	0.06	-0.03	0.05	0.08
11	-0.64	-0.60	0.00	0.00

n	$bn(L)$	$bn(R)$	$an(L)$	$an(R)$
2	OK	OK	OK	OK
3	OK	??	OK	OK
4	OK	OK	OK	OK
5	OK	OK	OK	OK
6	OK	OK	OK	OK
7	OK	OK	OK	OK
8	OK	OK	OK	OK
9	OK	OK	OK	OK
10	OK	OK	OK	OK
11	OK	OK	OK	OK

OK=Value between (mean- $\Delta-\sigma$ ) & (mean+ $\Delta+\sigma$ )